In view of these considerations, it seems difficult to deny that cases of inheritance of acquired characters have been brought forward. It would appear at any rate to be a choice between this Lamarckian interpretation and the view of Professor Weismann, that these useful directions of variation have been produced by the adaptive requirement, by means of selectional processes within the germ.

NOTES.

Exceptions found among Ungulates to ordinary slope on extensor surface of ulna are as follows:—

Oryx gazella. Oryx beisa. Strepsiceros kudu. Oreas canna. Alces machlis. Raphicerus campestris. Raphicerus melanotis. Ourebia nigricaudata. Ourebia hastata. Tetraceros quadricornis. Nesotragus moschatus. Cephalophus grimmi, C. rufilatus, C. leucogastris, C. abyssinicus, C. doriæ. Pudua humilis. Moschus moschiferus. Xenelaphus antisiensis. Hydropotes inermis. Dorcelaphus bezoarticus, D. americanus, D. hemionus. Cervulus muntjac, C. reevesi, C. lachrymans. Capreolus caprea. Elaphodus michianus. Cervus alfredi, C. porcinus, C. axis, C. duvauceli, C. elaphus, C. dama, C. cashmirianus.

Also certain Chevrotains and Suidæ noted.

Re A. Ungulates in which an Inguinal Whorl is found.

Bubalis caama. Rangifer tarandus. Cervicapra fulvorufula. Cervicapra arundinum. Cobus thomasi, C. buffoni, C. vardoni, C. leche. Equus hemionus. Bos sondaicus, B. indicus. Ovis ophion, O. ammon, O. sairensis, O. poli. Capra pyrenaica. Saiga tartarica (present in male, absent in female). *Gazella granti, G. mhorr. Antilocapra americana. Cephalophus dorsalis. Cervus kuhli, C. elaphus. Camelus bactrianus. Lama huanacus.*

Re B. Ungulates in which a Post-Humeral Whorl is found.

Strepsiceros kudu. Rangifer tarandus. Cobus leche. Equus hemionus. Equus burchelli (young). *Bos sondaicus, B. depressicornis. Ovis ophion, O. ammon, O. sairensis, O. poli. Antilocapra americana. Dorcelaphus americanus, D. dichotomus. Elaphurus davidianus. Lama huanacus.*

4. On the Structure and Anatomy of the Musk-Ox (*Ovibos moschatus*). By Dr. EINAR LÖNNBERG.

[Received April 25, 1900.]

CONTENTS.

In further elucidation of the relationships of the Musk-ox, I beg leave to offer the following remarks in continuation of those read before the Society on February 20th last[1].

[1] See P. Z. S. 1900, p. 142.

Sect. 1.—The Development of the Horns of the Musk-ox.

The peculiar shape, structure, and position of the horns of the Musk-ox make them more interesting objects for an investigation than the greater number of horns of other Cavicornia. The material on which this essay is based has been brought home by the Swedish Expedition to East Greenland in 1899, under the direction of Professor A. G. Nathorst, and consists of a skull of a young calf and several skulls of adult bulls and cows. Unfortunately no intermediate stages are represented by young or half-grown animals, because no such animals were seen, Professor Nathorst informs me. This gap is to some degree filled by Sir John Richardson's description and fine figure of the skull with the horn-cores of a yearling or "16 months old" bull [1]. With the aid of this description and figure, and above all by the extremely interesting markings of growth and structure which were made visible by preparing longitudinal sections of a horn of an old bull, I think that I shall be able to present a fairly exact sketch of the development of the horns of the Musk-ox. In preparing this I have had the valuable assistance of my friend G. Svenander, Cand. Phil., who has made the accompanying drawings of horns in three different stages of development, and to whom I therefore beg to express my best thanks.

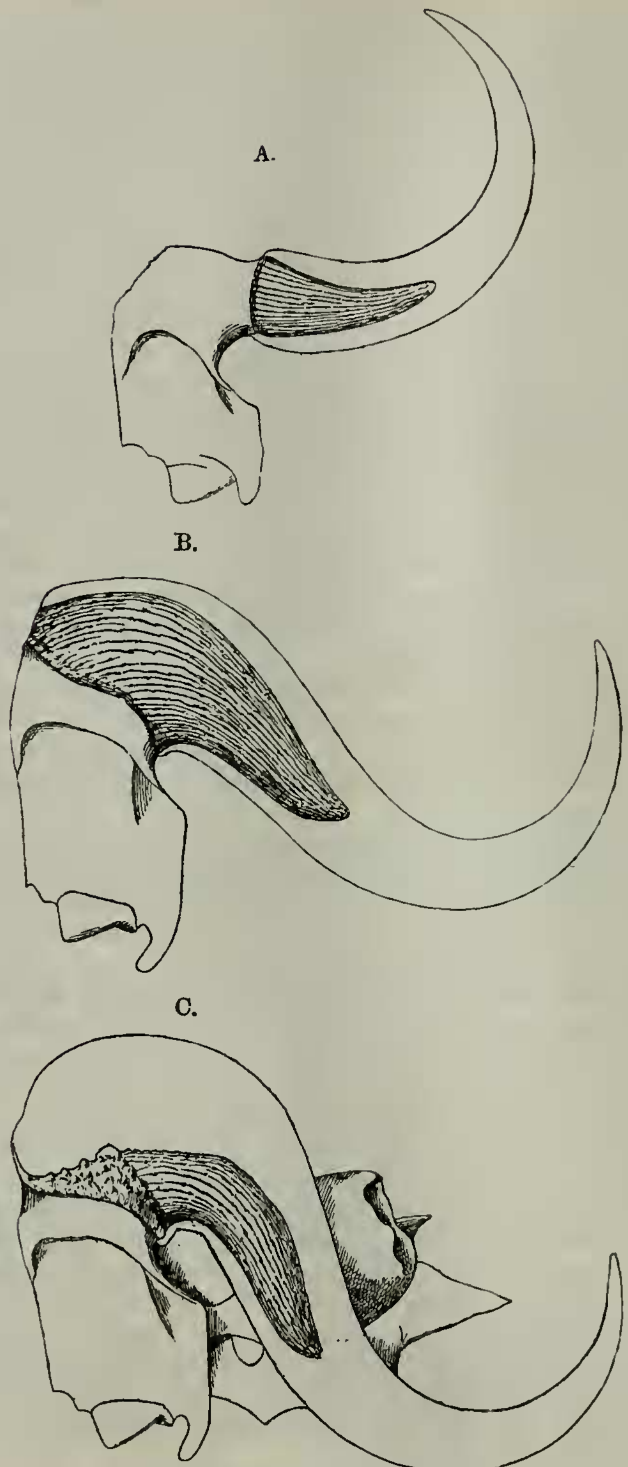
The origin of the horn-cores is conspicuous in the young summer calf as a slight prominence on the lateral surface of the frontal bone, about 1 cm. from the upper surface of that bone and about as far from the fronto-parietal suture, but $3\frac{1}{2}$ cm. from the posterior margin of the orbit.

The development of the horn must be slow during the first winter, because, as Mr. R. Lydekker informs me, the calves which were brought to Tromsö by a Norwegian vessel, and subsequently sold to the Duke of Bedford, had not any horns even in December.

In the second summer the growth must be rather rapid, as the horn-cores of a 16 months old bull according to Richardson's figure (*l. c.*) measure about 11 or 12 cm. The author mentioned describes them in the following way:—"The horn-cores have a purely lateral origin, and do not rise at all above the facial line, but, springing from an almost cylindrical root immediately behind the orbits, stand out laterally with a moderate inclination basilad and antiniad, their axis forming with the mesial plane of the cranium an angle of 62°. These cores are moreover, in themselves, concave on their facial or coronal aspect, by which they receive a uniform upward curve in the direction of their length, in addition to their general direction of outwards, basilad, and forwards. The tips of the cores in this yearling extend further from the sides of the skull laterally than any part of the massy core or its sheath in the four-year-old animal." With the help of this description, and assuming that the horns of an adult animal have not been

[1] Zoology of the 'Herald,' p. 67, pl. iv.

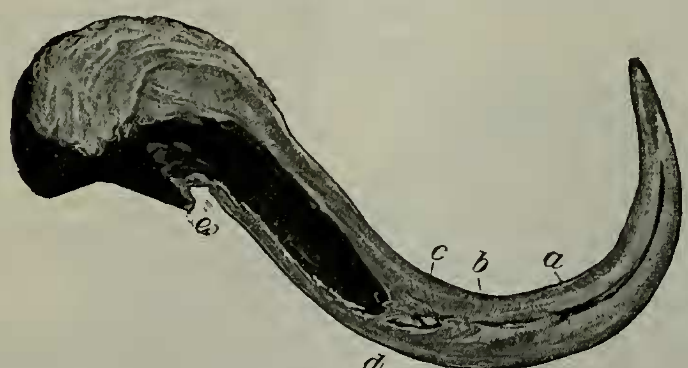
Fig. 1.



Schematic sketches showing different stages of development of the horn of the Musk-ox. A, represents the horn at the end of the first summer; B, an intermediate stage when the exostoses are at the height of their development; and C, a quite full-grown horn.

worn off in any higher degree than that a section from the tip of the horn in which such a horn-core fits fairly well corresponds to the original horn of that age, fig. 1 A is prepared. It is represented in the same plane as the main axis of the horn (as also is the case with figs. 1 B and C). Fig. 1 A should thus represent the horn of a young bull in the second autumn of its life. The longitudinal section of the horn of an adult bull, which is reproduced in fig. 2, shows that the horn has grown straight only until it reached a length of 5 cm. or hardly that, because already at that distance from the tip the originally ventral (later on distal) side of the horny sheath is thickened. Such a thickening of the ventral side of the horn produced by stronger growth of these parts effects, of course, the curving upwards of the tip of the horn. This curving upwards continues the whole of this period of growth, viz., the second summer of the animal's life. At the end of this summer the horns probably have attained a length of 35 cm., more or less, and their tips are at that time more raised above the facial line than at any later time.

Fig. 2.



Longitudinal section through a full-grown horn of the Musk-ox, showing lines indicating the growth at different periods.

I have above used the words "period of growth," for I think that the horns are chiefly enlarged during that time of the year when the animals are able to procure food in sufficient quantities not only to sustain life, but also to add to their bulk. Theoretically such an assumption does not seem too hazardous considering the circumstances under which these animals live. But the probability of this is strengthened by the fact that on the longitudinal section of the horn are seen some lines of demarcation which are most easily interpreted as the limits between such parts as have been added during different periods of growth[1]. At "*a*" on fig. 2

[1] Similar lines of demarcation are also seen on a longitudinal section of the horns of a common cow, and stand in that case plainly in connection with the rings at the base of the horn which in this country commonly are called "calf-rings," because it is known that a new ring, that is a new layer of horny

is such a mark, which is very pronounced: and I think that it may be regarded as the place where the distal tip of the horn-core was situated at the end of the first period of growth. Such a supposition corresponds also very well with the dimensions of the horn-core, as they have been given in Richardson's figure, compared with those of the horn.

During the second period of growth (third summer) the upper side of the horn is thickened by more rapid growth than that which takes place on the under side. Through this a pressure is effected by the horny sheath on the upper side of the horn-core, and this causes a reabsorption on the upper side of the same. On the lower side, on the contrary, the pressure is diminished and, therefore, the horn-core is thickened below by apposition. In such a manner the direction of the main axis of the horn is lowered. At the same time the length of the horny sheath is increased by basal growth, and it is driven out from the head in the direction of the axis of the horn-core on which it glides. In connection with this, new layers of horny substance fill up the end of the inner cavity of the horny sheath, and thus form the horny plug which can be seen on fig. 2 extending between "*a*" and "*b*."

Next period (fourth summer) the growth is continued mostly in the same way. The horny sheath is prolonged, and by stronger growth on the upper side the main axis of the horn-core causes reabsorption on its upper and apposition on its lower side[1]. During this period the plug between "*b*" and "*c*" is formed.

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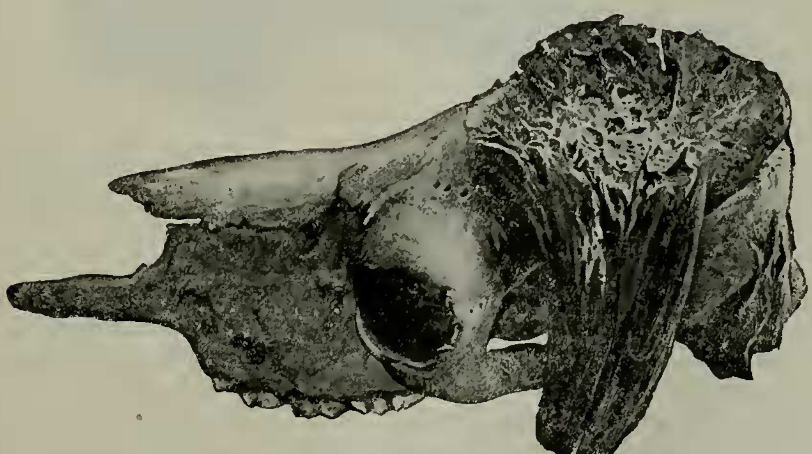
substance, is added after each act of parturition. The cause of this is, of course, the following: as long as the cow is gravid all superfluous nourishment is consumed for the growth of the uterus with its contents, and thus only little can be spared for the enlargement of the horns, but as soon as the calf is born there is material enough also for that purpose.

[1] That pressure can effect a transformation of bone through reabsorption and apposition may be proved by a great number of examples, but I shall here only recall a few. The enlargement of the brain-case of the mammals takes place in such a way caused by the pressure from within produced by the physiological growth of the brain itself. In this case reabsorption and apposition caused by the pressure are moments of the normal growth. When the dentist wants to straighten a set of teeth the members of which are placed obliquely or irregularly, he applies a pressure from the palatal side, and so the teeth which protrude behind the row move forward into the same rank as the others (provided there is space enough). This takes place in such a way that through reabsorption of the pressed parts of the alveolar walls new room is procured for the respective teeth to move forward, and by apposition from behind they become fixed in the new socket. It is in this case a transformation of bone produced entirely by artificial, mechanical power. But also pathological pressure can alter the shape of the bone. When by pressure of a parasite, as in the cases of pentastomids described by Hensel, mis-shaping skulls of Mustelids, prominences of the cranial wall are produced, or when a tumour is encased in bony tissue, these are also results of reabsorption and apposition. From these examples it may thus be concluded that a pressure on a bone which is not especially adapted to endure pressure, as the bones of the articulations and some others, has as a result that the bone gives way by reabsorption, but for the maintenance of the equilibrium compensating material is deposited by apposition. This rule is also applied for the core in the development of the horn in the Musk-ox.

In the following period the development continues also in the same direction. The horn is lowered, the horn-core points more downwards, and the plug between "*c*" and "*d*" is formed. At the same time that these changes are going on in the distal and middle portions of the horn, the base of the horn-core is enlarged and expanded over a great part of the frontals and parietals, on which large exostoses are developed. It is possible, although not fully proved, that the prominences which can be seen on the skull of the summer calf a little behind the first rudiments of the horn-cores, on the fronto-parietal suture, have something to do with the formation of these exostoses [1]. At their highest degree of development their appearance is such as is represented on Richardson's plate iii. (*l. c.*). As can be seen from that figure, they are highest, about 6 cm. or more, near the median line where they nearly meet from both sides.

By-and-by the horny sheath encroaches in a median direction over these exostoses, and when it has come so far that it caps over them it cannot be driven out any more or be prolonged, because its shape hinders this. Fig. 1 B (p. 688) is a schematic figure representing such a stage.

Fig. 3.



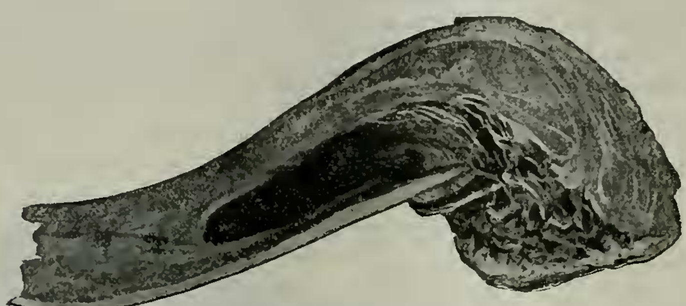
Lateral view of the skull of an old male Musk-ox, showing the horn-core and the remains of the reabsorbed exostoses.

The horn is, however, not yet fully formed although its length has reached its maximum. The continued growth tends to thicken the horny sheath, especially its upper layers. The bony substance

[1] This is on the supposition that the exostoses are pre-formed independently of the horn-cores, as seems at least partly to be the case in the Gnu. *Cf.* the interesting note on "The development of the horns of *Catoblepas gnu*" by F. E. Blaauw, Proc. Zool. Soc. London, 1889, Part I. On a skull of a young Musk-cow in the Zoological State Museum in Stockholm, there are also to be seen small exostoses quite independent of the horn-core and situated at a corresponding place.

of which the exostoses consist is reabsorbed and replaced by horny layers. It may be said metaphorically that the horny sheath eats down into the bony mass, which thus gets a rugged and pitted surface such as is seen on figs. 3 and 1 C. The pits and holes are filled up with horny substance. The interior surface of the basal part of the horny sheath is, in correspondence with this, densely beset with strong warty prominences, as can be seen in fig. 4. By this arrangement the horns become exceedingly strongly fixed to the skull, which is needed on account of the downward direction of the horn-core, which does not at all extend into the upward curve of the horn itself; every weight on or resistance against the hooked tip of the horn tends to pull the horny sheath of the core, and this would rather easily take place if it was not for this clinching of the

Fig. 4.



Lateral view of a longitudinal section of a horn of an old male Musk-ox, showing the structure of the inner part of the basal horn-layer, which has taken the place of the exostoses, and the lines indicating the periodical growth of the same.

basal parts to the bony mass of the skull. The horn cannot consequently be regarded as ready for use as a weapon before it is fixed to the skull in the manner described. Such an arrangement is also much more suitable than if the core should extend into the upward curve of the horn, because, as it is, the horn at the bend can be entirely filled up with horny substance, and thus be made much stronger at this place, on which the heaviness of a charge on the tip of the horn works most. If the core extended through the curve for the purpose of fixing the sheath, the horn at this place should consist of a comparatively thin layer of horny substance which could be relatively easily bent, and a central bone which would be broken even by a moderate charge.

That it is of great importance that the horn should be strong at the curve, and that it is used for heavy work, is proved by the fact that one of the bulls shot by Professor Nathorst had the tip of one of its horns broken in the bend at a place where it was $4\frac{1}{2}$ cm. thick. Such a breaking needs certainly a formidable strength and a heavy load.

The reabsorbing of the great exostoses and their replacement by horny substance takes place periodically, as can be seen from the distinct lines of demarcation which are visible on the section (cf. fig. 2, p. 689, and fig. 4, p. 692). These lines are wavy, thus showing the continuation of the warts mentioned above, and on account of the same origin parallel layers can also be distinguished. The reabsorption of the bony mass continues until the horny substance has reached down nearly to the fronto-parietal surface, but on the median and partly posterior side there remains a vertical lamella, thin as a leaf and perforated (as can be seen in fig. 3, p. 691). Anteriorly it extends horizontally under the horn. This thin crest lies close to the surface of the base of the horn, the base of which thus rests as in a thin basket[1] of bone constituting the remains of the former exostoses. These facts, especially the presence of the thin median lamella, which hardly could have been produced in any other way, proves that the formation of the basal parts of the horns has taken place exactly in the manner described above, and that thus the greatest exostoses belong to comparatively young though just full-grown animals, but that in old bulls the exostoses are more or less completely reabsorbed.

The last modification of the outer appearance and of the direction of the horns happens during this last phase of development just described. It has been said that during the last periods of growth it is mainly the layers of the upper side at the base of the horn that are thickened. These new layers, which are added from the interior, partly take the place of the reabsorbed bony mass, but grow of course upwards from the matrix, and exercise thus a great pressure from within on the outer layers which have been formed before. This pressure is so strong that the outer layers are broken and cracked, and through this the bases of the horns receive their peculiar aspect, described by Richardson as "very rough" and "coarsely columnar" (*l. c.* p. 67), and by Lydekker[2] as "marked by coarse longitudinal groovings." In old horns finally transverse cracks across the basal ridges add still more to the roughness of these parts.

It has been said above that the basal growth also influences the direction of the horn. This depends upon the fact that when the horny sheath is strongly thickened at its base on the upper side, such an addition of substance tends to protrude the sheath; but when this cannot be done because the base clings to the head in the manner described above, and when moreover there is no corresponding growth on the under side, the effect produced is a pressure on the originally upper, now outer or distal, side of the core, which accordingly is reabsorbed. Simultaneously the core is strengthened by apposition on its first lower, now inner or proximal, side.

Such views as these cannot be proved without histological

[1] This thin, perforated basket of bone can also be seen on figure 5 (p. 697) of a longitudinally sectioned skull seen from the inner (mesial) side.

[2] 'Wild Oxen, Sheep, and Goats of all Lands,' p. 780.

researches, and material of that kind was not on hand, but indications of a development in such a direction as described above are not wanting. In a section through the core at this stage, it is plain that the bony tissue on the outer side is more spongy and has a more rugged surface than on the median side, where the tissue is very dense and has a smoother surface.

The result of this is that the direction of the horn-core becomes still more vertical, as is shown in figs. 1 C (p. 688) and 3 (p. 691), and the whole horn is broken downwards. This is effected with such force that the thin basal wall of the lower side of the horny sheath, which is too weak to withstand the pressure exercised by the growth of the upper parts, is bent angularly, as can be seen in fig. 2 (p. 689) and in fig. 4 (p. 692).

When this last change has taken place the horn may be regarded as fully developed. The shape of the horns as well as their direction is somewhat different in different individuals. In some they are directed more forwards than in others[1]. The horns are often not even symmetrical in the same animal. Especially are the bases unlike, one being higher or broader than the other and so forth.

The most remarkable feature in the formation of the horn of the Musk-ox is perhaps the great changes to which the bony horn-core is subjected. Through reabsorption and apposition, it changes its shape and direction again and again. In the development of the horn of the Gnu an analogy to this is found. The first core of the young horns, which grow straight as spikes (cf. Blaauw, *l. c.*), forms nearly a right angle to the future core of a later period, and must therefore be completely reabsorbed to allow the growth of the horn. But also in the twice-bent horn of the Hartebeest no growth of the horn is possible without reabsorption and apposition, because the horny sheath cannot glide upward on the core—the less so as the middle portion of the sheath is narrower than the distal and proximal portion[2]. But straight, and many spiral, horns can easily grow without reabsorption of the horn-core, because the sheath can glide upwards without difficulty as its length is increased by basal growth.

Sect. 2.—Description of the Hoofs of the Musk-ox.

The hoofs of the Musk-ox have a very characteristic shape. The two main hoofs of each foot display on the whole a broadly rounded shape with posteriorly heart-shaped outline. The transverse diameter of the lower surface of the foot is as long posteriorly as at the middle, and a few millimetres longer than the longitudinal diameter. Each hoof has a convex upper and outer surface, is rounded anteriorly, has a deeply concave lower, and likewise very

[1] The animal which was the original of fig. 1 C (p. 688) had, for instance, its horns directed more laterally than in some other specimens.

[2] Some years ago Professor T. Tullberg drew the attention to this fact at a meeting of the Zoological Section of the Natural History Society of Upsala.

concave interior surface. Through this arrangement the plantar surface of the foot becomes concave, and in the middle there is a broad opening between both hoofs. This opening is about as broad as half the transverse breadth of each hoof measured separately. Through this opening or fissure between the hoofs, hair, growing between the fingers, protrudes to the lower surface of the foot, which otherwise of course is naked. But the hair of the leg hangs down on the hoofs, so that it is only a rather small portion of them anteriorly which is visible. Posteriorly this fissure is terminated by a transverse pad which very firmly unites both hoofs all the way to the treading surface, and consequently shares in supporting the animal.

The hoofs are a little irregular in shape, but not much so; and it can hardly be said that one hoof is more pointed than the other, because both are almost equally rounded. The fore hoofs are a little longer than those of the hind legs, so that in an adult bull the former measure about 12 cm. in length and the latter about 10 cm.

From what has been said above, it will be seen that the shape of the hoof is very different from that of the hoof of *Bos* and still more from the narrow pointed hoofs of the *Caprinæ*. In these animals the toes are not so closely and firmly connected posteriorly as in *Ovibos*. It seems more than probable that the shape of the hoofs of the Musk-ox is an adaptation acquired secondarily; and such a statement is plainly confirmed on comparing the similarly broadly rounded hoofs of the Reindeer, which lives under similar circumstances to the Musk-ox, with the pointed hoofs of other Deer.

The lateral hoofs of the Musk-ox are also comparatively large, and have a very characteristic shape and aspect because the vertical "Krallenplatte" does not together with the "Krallensohle," to use Boas's terminology [1], form an even cap over the rudimentary phalanges, but grows out so that it protrudes a good deal beyond the latter. This gives the lateral hoofs an irregular appearance as if they were torn. Although they are broad the lateral hoofs are not prolonged in such a way as in the Reindeer, and consequently the convergence with the latter animal is not extended to these parts.

Sect. 3.—Description of the Skull of the Musk-ox.

The osteology of the Musk-ox has been carefully described by Owen, Rütimeyer, Dawkins, and others. A renewed description of already known facts is consequently unnecessary, and it is not my intention to give one on this occasion. But I will proceed to a discussion of the characteristics of the Musk-ox skull based on a comparison with other forms, and through this I hope to bring forward some points which have been hitherto neglected or misinterpreted.

[1] Boas, "Zur Morphologie der Wirbelthier Kralle," Morph. Jahrb. xxi. 1894.

The material, consisting of a skull of a young calf and skulls of adult bulls and cows, was derived from the same source that I have already mentioned, namely from Professor A. G. Nathorst's Greenland Expedition in 1899. Intermediate stages are wanting for the reason, already mentioned, that no such stages were observed by the Expedition.

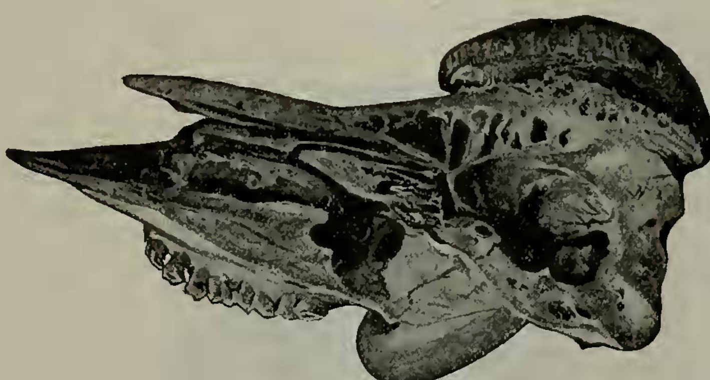
The most striking features in the skull of an adult Musk-ox are the situation and great development of the horn-cores and the protruding orbits. These characteristics indicate specializations from an ancestral type; and they have also, naturally enough, produced correlative changes of the skull. This must be borne in mind; and the primary and secondary conditions ought to be estimated at their right value with regard to the systematic position of the Musk-ox—that is, the changes of structure which have taken place during the development of the present specialized type *Ovibos moschatus*, and which separate it from other Cavicornia, ought, if possible, to be distinguished from those characteristics which are more ancient and which already belonged to the forms from which the Musk-ox has been differentiated. If the latter can be traced, they might give some hints as to the affinity and at the same time the systematic position of the Musk-ox; the former, on the other hand, would show in which points the animal has diverged from the common stock.

With regard to the arrangement of the frontals and the parietals, three principal types can be discerned among the Cavicornia, as has been pointed out by Rütimeyer [1]. Firstly, the Antelopes, with a horizontal parietal region, quite, or at least nearly, in the same plane as the frontals. Secondly, the Sheep and Goats, in which the fronto-parietal plane is bent in an angle which forms a transverse ridge on which the horn-cores are situated; this "Knickung" has taken place on the frontals, and the parietal region slopes more or less steeply towards the occiput: and thirdly, the Oxen, in which the frontals alone form the roof of the brain-case and in which the parietals have been pressed backwards and towards the sides. The position of the horn-cores is also very characteristic for each of these three groups, although exceptions are found. As a rule, the horns of the Antelopes arise above or near the orbits. In the Goats and the Sheep the horns are placed on the transverse frontal ridge, which in them forms the summit of the head. The Oxen have their horns situated in the posterior corners of the skull at a considerable distance from the orbits. These three groups may thus be regarded as representing three different types of development, although of different value. The first is, of course, the most primitive, from which the others may be derived. The second and third have in different ways reached the same goal, namely of getting the horns on the most effective and suitable place, that is on the summit of the head. If it is asked, now, to which of these types does *Ovibos* show the greatest likeness, it is evident that the

[1] 'Versuch einer natürl. Geschichte des Rindes,' Zürich, 1867.

answer must be the first, or Antilopine, in fact the primitive one. The fronto-parietal region forms a perfect plane without the slightest trace of "Knickung," and the parietals are fully developed and partake in the roofing of the brain-case. It is accordingly quite evident that this part of the skull of the Musk-ox shows no affinity either with the Oxen or with the Sheep, but is of the more primitive Antilopine type [1]. The origin of the horn-cores in *Ovibos* is different from that of the Antelopes, as it is perfectly lateral. In the skull of a young Musk-calf shot by Professor Nathorst on the 26th of August, and thus probably about three months old, the beginning of the horn-core appears as a small tubercle situated about 4 cm. behind the orbit, and about 1 cm. from the *sutura coronalis* [2]. The horn-core thus originates only on the frontal bone, but its base expands gradually with age in a median as well as backward direction, so that in an old bull, as is well known, it covers not only the posterior portion of the frontal, but also the whole parietal as far as the *sutura lambdoidea*. In this way the same effect is produced in *Ovibos* as in the Ovina and Bovina, viz., the horns get their insertion on to the vertex of the skull. The

Fig. 5.



Section of skull of Musk-ox.

result is, however, obtained by quite different means in the three types, and the vertex is not situated in the same cranial region. It must also be remembered that the Musk-ox ontogenetically and gradually passes through all intermediate stages of its development from the primitive one; but this is not the case in the others.

[1] The fronto-parietal and the occipital planes form a right angle with each other, and the highest point of the Musk-ox skull is therefore at the *sutura lambdoidea*.

[2] There is a more pronounced tubercle situated at the edge between the upper and lateral surfaces of the skull, and divided by the *sutura coronalis*. This cannot, however, be the origin of the horn-core, as it becomes evident from Sir John Richardson's figure that the horn-core in a 16 months old animal is still situated only on the frontal bone.

Ovibos must therefore be regarded as less distinct from the ancestral Cavicorn types from which the development of all three, *Ovibos*, *Ovis*, and *Bos*, has diverged.

The direction of the horn-cores of *Ovibos* is quite different at different ages, as has been described in the section treating of the development of the horns. The frontal sinuses (cf. fig. 5, p. 697) are very large anteriorly, so that in an old bull the vertical diameter of the lumen of these sinuses just above the anterior border of the brain-cavity, where at its deepest, measures 45 mm. Just in front of this place is a vertical and transverse septum situated above the *lamina cribrosa*. In front of this the frontal sinus forms one large cavity which is nearly undivided and measures 6 cm. in length. Posteriorly from the septum mentioned, the frontal sinus is divided into several loculi by vertical septa, as can be seen in the figure. The sinus extends into the base of the horn-core as far as 2–3 cm. reckoned from the lateral or inferior line of insertion of the horn-core (cf. fig. 6). But although the base of the horn-core is taken up by rather large vacuities, the greater part of the same is devoid of such (fig. 6). In the specimen (an old bull) from which the above description is taken, the length of the horn-core, lacking vacuities, is 14 cm. The interior of this part of the horn-core is

Fig. 6.

Section of a part of the skull of the Musk-ox.

In this figure the horn-core is sectioned longitudinally, and the anterior portion is moved to the side and exposes its interior surface on the right side of the figure.

constituted by spongy bony tissue forming a layer about 20–24 mm. in thickness. This is again surrounded by a cortical layer, 6–10 mm. in thickness, of solid bone which, especially on the proximal side, is very dense (cf. fig. 6). The outer surface of the horn-core is, as can be seen from the figures, very rugged and also partly spongy. From this description it may be concluded that the structure of the horn-cores of *Ovibos* is quite different from that of the Oxen, in which the vacuities extend through the whole length of the horn-core. In the horn-core of Goats the vacuities extend through three fourths of the length of the horn-core, but in Sheep only a little more than a fourth [1]; the bony tissue is much more spongy in the latter.

From this it may be seen that *Ovibos*, in which the sinuous portion of the horn-core is only about a sixth of its length, represents a stage more like that of the greater number of Antelopes, or is, in other words, perhaps in a more primitive condition. It is, however, doubtful how much importance ought to be ascribed to the extension of the air-cells or sinuses in the horn-cores. By the above statements, it is shown how different the closely allied genera *Capra* and *Ovis* are in this respect. In *Nemorhædus* the sinuses extend through half or more than half of the horn-core, according to A. Milne-Edwards's figures [2]; but in *Rupicapra* the horn-core is only hollow at its base for one-tenth of the length. In both the latter genera the horn-cores have the same straight upward direction, so that such a condition does not seem to influence the development of the sinuses, as perhaps might be supposed from the difference in this respect between Goats and Sheep. On the other hand, the Buffalo with its horizontal horn-cores has large sinuses extending to the tips.

The parietals of the Musk-ox do not contain any sinuses or air-cells but are very thick and massive (cf. fig. 5, p. 697), so that their diameter in an old bull is 47 mm. measured a little in front of the *sutura lambdoidea*. It has been said above that the frontals and parietals lie in the same horizontal plane. This is already the case in the young calf, and is thus a primitive condition which has been retained; not an acquired characteristic, as it must have been if *Ovibos* were the direct descendant of the fossil *Bootherium* Leidy, and the latter derived from the Sheep. Rütimeyer [3] seems inclined to assume this for the purpose of more easily explaining the, according to his opinion, ovine origin of the Musk-ox [4]. It is, however, so far as I can judge, less probable that a form originating from ancestors with an even fronto-parietal region, such as the primitive ruminants must have had, should have acquired a specialization in form of a frontal elevation or "Knickung" as a base for the horns; and then again, without reduction of the horns, returned from such a specialization to the original arrangement of the frontals and parietals and devised, so to speak, a new plan for fixing the horns in a more suitable manner. That is, in other words, a reversion from the ovine specialization of the skull to the primitive antilopine

[1] This may be subjected to some variation, but I make my statements from the material at hand.

[2] Milne-Edwards, Rech. pour servir à l'hist. nat. des Mammifères (Paris, 1868–74), pl. 71 *a*, pl. 73.

[3] Versuch einer nat. Gesch. d. Rindes, ii. pp. 17–20.

[4] But if *Ovibos* was descended from *Bootherium* which had a "Knickung" of the frontals, it would be expected that the calf of the former would show some traces of likeness in this respect to its supposed progenitor, which however is not the case, as already stated.

type is improbable, at least as long as the armature—the horns—which have been the cause of the development, are retained. But there is no difficulty in assuming that from the same indifferent type have been developed forms which have specialized their armature differently, the one as *Ovibos moschatus* and the other as "*Bootherium*" or *Ovibos bombifrons*; and that in such a case the latter has acquired a characteristic, the frontal elevation, which offers some resemblance to the ovine type. But then this is only a parallel, and proves no affinity with the ovine type. There seems also no need for assuming *Bootherium* as being older than *Ovibos*, as both have occurred in the Pleistocene[1].

In a young calf of *Ovibos*, the length of the parietals near the median line is 40 per cent. of the length of the frontals measured in the median line. This relation, however, diminishes with age, so that in an old bull the corresponding percentage is 30–35. It is, however, a little difficult to perceive the sutures at the surface between the frontals and the parietals, but the *sutura lambdoidea* is distinguishable, although nearly obliterated, even in the oldest skull I have seen. The parietal zone on the top of the head is thus already in the calf, compared with the frontal region, shorter than in many Antelopes (*Gazella*, *Cephalophus*, *Nemorhædus*, *Rupicapra*, &c.). In the Sheep and the Goats the relation varies a good deal, but in many cases the parietal zone is not even 30 per cent. of the frontal, and is accordingly more reduced than in the Musk-ox. The latter seems thus, with regard to the development of the parietal region, to occupy an intermediate position between the Sheep and the more primitive Antelopes.

On the sides, the parietals of the Musk-ox extend with a rather short and truncate portion forward between the frontal and squamosal. The anterior end of this portion reaches only half-way between the orbit and a vertical line drawn through the *meatus auditorius externus*. This shortness of the lateral portion of the parietal in the Musk-ox has the result that the frontal meets the squamosal, and forms with it a rather long suture on the lateral

[1] I must confess, however, that I only know *Bootherium* from the figures published by Boyd Dawkins (Palæontographical Society, vol. xxv. Monogr. on the Brit. Mamm. of the Pleistocene, genus *Ovibos*, pl. v.), and from descriptions. Fig. 3 on the plate quoted is said to be a coronal view of the skull of *Bootherium bombifrons* Leidy, and is regarded by Dawkins as belonging to an adult female. It is, however, rather similar to the aspect of the skull of a young Musk-ox, and ought to be compared with Sir John Richardson's figure (Zoology of the 'Herald,' pl. iv. fig. 2). Fig. 4 on Dawkins's plate is said to be a lateral view of the same, which nevertheless is hardly possible, to judge from the general appearance as well as from the dimensions. Dawkins's fig. 4 of *Bootherium cavifrons* Leidy is regarded as belonging to an old male, which seems very probable from comparison with the Musk-ox, in which the large exostoses at the base of the horn-core get reabsorbed in old age. These forms may belong to the same species, representing the female and the male form, as Rütimeyer and Boyd Dawkins have suggested, but their ovine affinities I cannot see. When Rütimeyer says (*op. cit.* p. 18) that the horns of *Bootherium* have been "ohne Andeutung einer rückwärts Beugung der Spitzen," it must be remembered that the horn-cores of these animals are so short that they indicate only the direction of the basal parts of the horns.

wall of the skull behind the orbit. The length of this squamoso-frontal suture equals half the vertical diameter of the orbit. This remarkable arrangement seems to be peculiar to the Musk-ox. In Sheep, Goats, and most Antelopes [1], as well as in *Bos bubalis*, the anterior lateral portion of the parietal meets the sphenoid and excludes the frontal from the squamosal. In *Gazella dorcas* there is a short suture between the squamosal and the frontal. Such a suture is also found in *Bos taurus*, in some specimens of which it attains a considerable length although not such an extent as in *Ovibos*.

In the calf two interparietals are found in the median line between the parietals and the supraoccipital. They form together an oval figure with 19 mm. transverse and 13 mm. longitudinal diameter. In the adult cow they have been separated from each other in the median line, but are not anchylosed to the parietal or the occipital. In the adult bull they are not conspicuous.

The angle between the parietal and occipital regions is straight. In the calf the occipital is visible from above, forming a zone as broad as its own thickness. In the adult cow the same condition is found, but in the oldest bull the parietal has extended more backward, so that the occipital zone of the coronal surface is more or less covered.

It is evident from this description that the supraoccipital forms only the vertical posterior wall of the brain-case. This is a difference from the condition found in Sheep, Goats and many Antelopes [2], in which the interparietal is anchylosed to the supraoccipital so that it looks as if the latter was angularly bent forward in the parietal plane and partook in the formation of the posterior roof of the brain-case. The *sutura lambdoidea* is in the Musk-ox plainly conspicuous even in old animals just behind the base of the horn-cores. It becomes first obliterated in the median line. The shape of the occipital region has been described by Richardson (*l. c.*) and Rütimeyer. Strong muscles are needed, especially in the bull, for supporting the heavy head ; and for that purpose a strong occipital ridge extends downwards in the median line. Laterally under the *crista lambdoidea* there are deep grooves for the insertion of muscles. The supraoccipital does not reach the *foramen magnum*, but is excluded from it by the exoccipitals, as can be seen in the skull of the calf. The thickness of the supraoccipital is exceedingly great, measuring in an old male 28 mm. (fig. 1, p. 688). The peculiar shape of the condyles is described by Richardson (*l. c.* p. 69), who has also drawn the attention to the "exterior heel that occupies much of the space between the condyle proper and the paroccipital spine and furnishes a pulley or trochlea, which moves on a concave pretty broad articular surface, formed by a lateral notch in the brim of the atlas." In the calf this heel is not developed at all, and in the cow only a little. It is thus a

[1] *Nemorhædus, Cephalophus, Antilope, Saiga, Gazella* (partly), *Bubalis*, &c.
[2] *Nemorhædus, Antilope, Saiga, Gazella, Cephalophus*, &c.

special adaption for the Musk-bull. Rütimeyer says (*l. c.* p. 9) that he does not know any analogy to this except possibly slight traces "bei dem Gnu und beim Schaf." He thinks that it stands in connexion "zu dem unverhältnissmässigen Gewicht des Kopfes." I do not think, however, that it is a structure formed only for the purpose of more easily carrying the weight of the head, as, in such a case, a similar arrangement ought to be found at least in some of the different animals with a head comparatively as heavy as that of the Musk-ox, for instance in *Ovis poli* Blyth. This form has, as I have had the opportunity of seeing in the Zootomical Institute of the High School in Stockholm, a very massive and stout occipital region, but no lateral extension of the condyles. It is rather an adaption for the strengthening of the occipital joint in a transverse direction, which is needed for the use of the horns as weapons. The horns are, as is well known, placed so that their upturned points are situated at a considerable distance from the median line of the head. From their shape and arrangement it is evident that they are used sideways. That is, when hooking a foe, the Musk-bull does not move its head vertically up and down in the sagittal or median vertical plane; in such a case the usual articulation would have been satisfactory, or the articulating surfaces would have extended in a median direction, as is often the case in *Bos*[1]. The movements of the Musk-ox when hooking are carried out obliquely or in a more or less transverse vertical plane[2]. In such a way the horns become formidable weapons, but as the lever is rather long a strong fulcrum at the base of the head is needed, and this is afforded by the transverse extension of the articulation between atlas and occiput.

The horns of the cow have not exactly the same position to the head as those of the bull. They are directed more forward and less outward, at least in the specimens I have seen. This, together with the fact that the horns of the cow are weaker and probably less used as weapons than those of the bull, may explain the difference in the development of the occipital articulation of the male and female of *Ovibos*. Nevertheless, the occipital region is also in the cow very stoutly built, and the interspace between the condyles and the *processus paroccipitalis* (*paramastoideus*) is more filled out with bone than in other Cavicornia.

Boyd Dawkins (*l. c.*) and Rütimeyer[3] compare the *processus paroccipitalis* of *Ovibos* to those of the Sheep and the Argali. Such parts as merely serve for the insertion of muscles are, naturally enough, easily subjected to changes in shape and structure, and thus of comparatively little value for systematic purposes. This

[1] Such an extension of the articulating surfaces in a forward direction can also be observed for instance in *Oreas canna*; in species of *Cervus*, and in *Antilocapra*, it is remarkably great.

[2] That the tips of the horns are used, and not only the basal parts, is proved by the fact that in some specimens the points are plainly sharpened by wearing or polishing against something hard, and moreover one of the bulls shot by Professor Nathorst had the tip of one horn broken off.

[3] 'Die Rinder der Tertiär-Epoche,' Zürich, 1877 & 1878.

can also be seen in the ontogenetic development of the Musk-ox. In the calf these processes are quite flattened from the sides as in *Bos* and many Antelopes, which perhaps is the primitive shape, as it is found in so many different forms. Later, in adult animals, the processes become thickened in such a way that they become triangular in section through the development of a lateral crista whereby a broad posterior face is produced. Distally the processes become compressed in an antero-posterior direction and end in a transverse edge. These modifications are of course effected for the purpose of getting larger space for the insertion of the muscles, and I do not lay much weight upon them: I mention them only to show that the *processus paroccipitalis* of the Musk-ox does not much resemble those of the Sheep, which are posteriorly narrow, slender and tapering towards the tips. These processes of the Musk-ox are slightly curved towards the median line [1], although not so much so as in the Sheep, Oxen, Buffaloes, and many other ruminants. They cannot be termed small (cf. Rütimeyer), as their length in an adult bull measures about 3 cm., which is as much as $\frac{1}{4}$ of the height of the occipital region from the lower surface of the condyles to the *sutura lambdoidea*. The same relation is already found in the calf (resp. 2 cm. and 8 cm.).

"The basi-occipital bone in *Ovibos moschatus* is quadrate in outline," Boyd Dawkins says (*l. c.*). In the young calf it is quite hexagonal, but with age the posterior sides are shortened so that the corpus of the bone becomes quadrate in outline; and therein lies of course a certain similarity with the Sheep, but also with several Antelopes. It seems, therefore, contrary to Dawkins's opinion, questionable whether this characteristic can be of any other value than that of separating these animals from the Oxen, which have the basioccipital bone differently shaped. Dawkins also points out the difference between *Bos* and *Ovibos* with regard to the anterior muscular impressions of this bone, the former having them "supported on a tuberosity." Such things are of little importance; but as the question is open to discussion, it may be mentioned that in Sheep and Goats these impressions are situated at the sides, partly on the lateral surface, of the bone, and separated by a smooth area nearly as broad as the bone. In the Musk-ox, on the contrary, the same impressions cover the ventral surface of the bone so that they nearly meet in the median line in the adult male, but do not extend laterally (fig. 7). The basi-occipital of the Musk-ox is traversed by a low median keel which is already indicated in the calf. Richardson's exact description (*l. c.* p. 69) of these parts need not be repeated.

The auditory bulla is subjected to considerable ontogenetic changes, as can be seen from the following measurements. In the calf it is rather large and inflated. Its length is 39 and its greater width 20 mm. In the adult cow it also looks inflated,

[1] This may be subject to variation, as Richardson says that they "descend straight," but Rütimeyer found them "einwärtsbogen wie beim Argali."

but it is hardly as large as in the calf, measuring 42 mm. in length but only 17 in width. In an adult bull the same measurements are (not counting spines) 31 mm. in length and 14 in width. The shape of the bulla cannot therefore be of classificatory value in this animal.

The *pars mastoidea* is visible on the occipital surface as a narrow strip between the paroccipital and the squamosal, which latter forms the lateral margin of this surface. At the upper end of the mastoid there is, in the calf, a small separate bone visible, with an outer surface measuring 8 mm. in diameter. It is intercalated between supraoccipital, paroccipital, mastoid, and squamosal.

It has already been mentioned that the squamosal constitutes the lateral margin of the occipital surface. This bone forms a strongly projecting edge posteriorly, which extends downward and forward in an even curve to the base of the zygomatic process, thus making a posterior termination and a broad floor to the temporal groove, which is roofed over by the horns. There is accordingly only an (in the bull, narrow) opening posteriorly in an oblique upward direction over the parietal zone. Rütimeyer [1] seems to lay some weight on this opening as a difference from the Oxen and a resemblance to the Sheep. But, compared with the condition found in the Italian Buffalo, there is not much difference in this respect, and in nearly all Antelopes "die Schläfengrube öffnet sich . . . auch nach oben." It is consequently only the most specialized members of *Bos* in which "die Parietalzone seitlich die Schläfe überdacht," as the same author in his first paper rightly puts it. Later Rütimeyer, like some other authors [2], seems only to think of two possibilities, *i. e.* "Is *Ovibos* a Sheep or an Ox"? and then every aberration in structure from the specialized type is regarded as a similarity to the ovine one, even if it is a feature common to most ruminants.

The articulating surface for the condyles of the mandible is very broad (see fig. 8, p. 709) and, to judge from my material, more convex in the cow than in the bull, in which it is almost flat. There is a broad and strong *processus postglenoideus.*

So far as my material allows a judgment, there are always two *foramina temporalia* in the Musk-ox, but only one in Sheep or Goats. This is, however, a less important and variable characteristic [3].

The great development of the orbital tube is one of the most conspicuous features of the Musk-ox skull, as has also been mentioned by previous authors. [It is formed by the frontal to, roughly speaking, an extent of a little more than two-fifths (more exactly $\frac{5}{11}$) of the posterior and upper portion, by the lachrymal to one-

[1] 'Die Rinder der Tertiär-Epoche.'

[2] Boyd Dawkins, for instance.

[3] *Nemorhædus. Cephalophus, Bos taurus,* &c. seem to have two; *Antilope, Saiga, Gazella, Rupicapra, Bos bubalis,* &c. only one.

This is mentioned here only because Rütimeyer says (Rind. Tert. p. 104): "Im übrigen folgt der Schädelbau (viz. of *Ovibos*) . . . . . demjenigen von Schafen bis in kleine Details, wie etwa Gestalt von Gefäss und Nervenrinnen."

fifth ($\frac{2}{11}$) anteriorly, and by the jugal to a little less than two-fifths ($\frac{4}{11}$) inferiorly. The length of the orbital tube is, in an old bull, between 6 and 7 cm. posteriorly and about $4\frac{1}{2}$ cm. anteriorly. In a cow the same measurements are about 5 and $3\frac{1}{2}$ cm. respectively. Already in the young calf the orbits protrude about $2\frac{1}{2}$ cm. measured posteriorly.] The reason why the orbital tubes have attained such a great development is double, but easy to understand. Firstly, a look at the skull of the Reindeer compared with those of other Cervicornia, teaches us that a ruminant, living in Arctic regions, and therefore provided with a long fur, is apt to develop a tube-like prolongation of the orbital ring for the purpose of not getting the eyesight hindered by the long hairs. This may be certainly applied to the Musk-ox also. It may be added, further, that the situation of the horns probably would to a great extent prohibit the animal from noticing any object, except those just in front, if the eyes were not protruding. Secondly, when for the reasons mentioned the eyes have become protruding, the peculiar development and position of the horns make a strong protection for the eyes, and one well needed; for it has already been said that when a Musk-bull charges he uses his horns sideways or at least obliquely. It is thus evident that the eye easily could be damaged, as it is just in the way of attack, if it were not protected by its thick bony case. That the eye-tube is meant for protection can also at once be seen from the heavy structure of the bony wall, which in an adult bull, above and below, reaches a thickness of more than $2\frac{1}{2}$ cm. The lower thickening is produced by the enlarged jugal, and the upper one by a stout ridge beginning on the lachrymal and extending in a median direction over the frontal to the neighbourhood of the *foramina supraorbitalia*. This ridge is also very useful when the bull is butting with its forehead. The orbital tubes are, however, not a new organ acquired by *Ovibos*, but only a development and prolongation for certain purposes of an orbital ring such as it exists not only in the Sheep, but also in a great number of Antelopes, e. g. *Antilope*, *Saiga*, *Gazella*, *Rupicapra*, *Nemorhædus* (at least some species), &c.,[1] in which the direction of the orbital brim is the same as in *Ovibos*, although much narrower. It is, therefore, no reason whatever to regard the orbital tubes of *Ovibos* as an excessive development of the orbital ring of the Sheep or, to use Boyd Dawkins's words, "a decided ovine affinity" (*l. c.* p. 7).

As a result of his comparing the Musk-ox only with Oxen and Sheep, Rütimeyer (*l. c.* p. 10) writes: "Dem Schaf folgt dann auch ferner in jeder Beziehung die Bildung des Thränenbeines." It is chiefly the presence of a lachrymal groove which has created such an opinion, I think; but, as I have shown in the previous paper, the presence of an anteorbital gland is far from being an exclusively ovine character, and accordingly a lachrymal groove or pit is just as little so. The bending outward of the lachrymal bone for its

[1] Not to mention distant forms such as *Antilocapra*, Reindeer, Camel, &c.

share in the formation of the orbital tube, makes this pit look deeper than it really is. If the bone were straight this pit would be rather shallow. The shape of the lachrymal bone is different from that of the Sheep. It is broader and decidedly widened in front, where its breadth is about a ninth of the cranial length; whereas the lachrymal bones of the Sheep usually are narrowed in front or at most linear.

The suture between the lachrymal and the nasal bones is quite variable in length in the different specimens of Musk-ox. In my material this variation is from 25 to 5 mm. Richardson (*l. c.*) has treated of this as well as of the shape of the nasals. He has also observed that the nasals of the Musk-ox differ from those of the Sheep as well as from those of the Oxen. But it is evident that no characteristics of systematic value can be obtained from such variable bones as these. It may, however, be mentioned that a flat and broad nasal region, about $\frac{1}{7}$ of the basal length of the skull, is a feature common not only to *Ovibos* and the Caprina but also to a great number of Antelopes, when compared with the Bovina, in which the nasal region is more or less compressed to a ridge and thus narrowed to about $\frac{1}{8}$ of the cranial length. The great thickness of the nasals is in concordance with other bones of the Musk-ox skull, as may be seen from fig. 5 (p. 697).

The intermaxillaries do not reach the nasals. Their proximal portion is curved outwards a little, but the distal parts are rather strongly convergent, and through this the distal portion of the upper jaw becomes comparatively more narrow even than in the Sheep. In consequence of this, and because the intermaxillaries are thickened in the middle, the anterior part of the skull gets a characteristic aspect not seen in other Cavicornia. In Sheep as well as in Oxen the posterior extension of the intermaxillaries is subjected to variation. It is, however, perhaps worth mentioning for comparison, that in none of the genera *Budorcas*, *Nemorhædus*, *Haploceros*, and *Rupicapra* do the intermaxillaries reach the nasals.

It might be that the shortness of the intermaxillaries stands in relation to the Musk-ox's way of browsing with its thick lip instead of biting. The Reindeer, which has thick lips, has a short intermaxillary not reaching the nasal; but *Cervus dama*, for instance, with thin lips has a long suture between the intermaxillary and the nasal. There seems accordingly to be a certain correspondence or parallelism between the Reindeer and the Musk-ox, which is also visible in the shape of the thick and anteriorly pointed intermaxillaries.

The *foramina incisiva* of the Musk-ox are very large and posteriorly narrowed. *Ovibos* resembles in this respect the Sheep, but also *Nemorhædus*. These foramina do not offer any important characteristics.

The palatal surface is concave and rather strongly constricted behind the *foramina incisiva* (fig. 7, p. 707), much more than in *Bos taurus*, but much less than in *B. bubalis*. The palatines are larger comparatively than in the Sheep. The suture between palatines and maxillæ is characteristic and wavy, because each palatine has a median and a lateral lobe extending forward on both sides of the *foramina palatina* (fig. 7). The molar series are a little arcuate and converge anteriorly, so that, for instance, in an adult bull the distance between them is anteriorly 56 and posteriorly 84 mm., measured at the alveolar brim. The length of the molar series in the same specimen is 144 mm. The length of the molar series compared with the basal length of the skull is in a cow 32 per cent. and in a bull 31 per cent. of the latter measurement [1]. The palate extends well backwards so that the choanæ open behind a line connecting the posterior edge of the last molars. This seems to be a difference from the condition of the Caprina as well as that of

Fig. 7.

Palatal surface of skull of Musk-ox.

many Antelopes (*Nemorhædus*, *Rupicapra*, *Gazella*, *Antilope* [2], *Cephalophus*, &c.). On the other hand, it offers a superficial resemblance to the Bovina.

The extension of the masseter muscle in a forward direction over the lateral surface of the maxillary is comparatively short, probably because it has such a wide area on which it may expand, below the orbital tube (fig. 3, p. 691). As a result of this, the *crista*

[1] This relation between the length of the molar series and the basal length of the head seems to be pretty equal in the ruminants. The following results may be quoted to prove this: in a Buffalo the molar series measured 30·0 p. c. of the basal length of the skull, in a common Ox 29·3 p. c., in a Goat 31·1 p. c., in *Nemorhædus* 32·3 p. c., in *Rupicapra* 29·7 p. c., in *Gazella* 34·1 p. c., in *Antilope* 31·0 p. c., in *Cephalophus* 33·3 p. c., in the Wapiti 32·8 p. c., in the Reindeer 27·9 p. c.; but in *Saiga*, with its reduced number of teeth, not less than 29·8 p. c., and so on.

[2] In the Saiga the choanæ open behind the molars, a fact which may stand in relation to the reduced number of molars.

masseterica in an adult bull passes about a centimetre from the lower margin of the lachrymal bone and parallel with the same, but then it descends rather steeply to a *tuber maxillare* situated above the second true molar. This is constant in my material except in one bull, in which the *tuber maxillare* is situated on a vertical line drawn between the first and second true molars (fig. 3, p. 691). But there seems to be still more variation in this respect, because Rütimeyer (*l. c.* p. 11) as well as Dawkins (*l. c.* p. 7) assert that the *tuber maxillare* is to be found above "the first true molar." It is apparent from these facts that the situation of the *tuber maxillare* does not offer any valuable characteristic for classification.

The *foramen infraorbitale* opens rather far back, as Rütimeyer also remarks, above the third premolar or even first true molar. This seems to be a singular feature among Cavicornia. In Sheep, Goats, and Gazelles this foramen is situated above the second premolar, and in other forms it is still more advanced. *Budorcas* (including *Nemorhædus* &c.) agrees with *Ovibos* in this respect, as will be seen later.

The mandible of *Ovibos* offers several points of interest. The *processus coronoideus* is strongly curved backwards and more pointed than is usual in other forms. It is also strikingly small, which can be expressed by comparing its length with the length of the mandible itself. The former measurement is in *Ovibos* about 16–17 per cent. of the latter, but in Sheep, Goats, and Gazelles about 24 per cent., in *Rupicapra* about 23 per cent., &c. The small Cavicornia seem as a rule to have their *processus coronoideus* more straight, thin, and squarish at the end. In *Bos* the condition resembles more that in *Ovibos*, with the length of *processus coronoideus* about 18·5–20 per cent. of the mandibular length. This may, therefore, be regarded as a parallel development, the more striking as the most specialized *Bos taurus* has a shorter and more pointed coronoid than *Bos bubalis*.

The articular surface of the mandible of the Musk-ox is remarkable for its shape, because the longitudinal diameter is about six tenths or more of the transverse one. In other ruminants the transverse diameter is at least twice (sometimes nearly thrice) as long as the longitudinal one.

The *symphysis mandibulæ* (fig. 8, p. 709) is about as long in *Ovibos* as in *Bos* (16 per cent. of the mandibular length in the former and 14·17 per cent. in the latter); but it is, as Richardson rightly remarks (*l. c.* p. 70), "more vertical, and it forms an angle or chin." The formation of such an angle or chin at the *symphysis mandibulæ* may be caused by the need to strengthen the symphysis in a vertical direction, because the opening of the *canalis inframaxillaris* is very wide and deeply excavated in the bone and thus weakens the bone. The great width of this canal may be due to the conditions under which the Musk-ox lives in the Arctic regions. It is not only this foramen which is comparatively large in *Ovibos*, but the foramina for blood-vessels are as a rule large. Rütimeyer has